

FOREWORD TO  
SCHEDULES OF REINFORCEMENT

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I

*Schedules of Reinforcement* (*Schedules*) is an extraordinary monograph. It is an account of exciting scientific discoveries that were both important and original. The material was quite unfamiliar except to a small coterie who had been close to the work. A monograph of this magnitude is normally preceded by a series of technical papers in the scientific literature, describing reasonably coherent fragments of the work as it progresses, so that people in the field can have some familiarity (which often passes as understanding) with the new discoveries. But *Schedules* was not preceded by papers. It appeared full grown in 700 pages of almost entirely original material. To most psychologists even the nomenclature was unfamiliar, although some terms had been used before. In a word, it was an uncompromising challenge. Here it is, a mother lode of information on new discoveries: Go ahead and mine it. There are substantive written sections, mostly in the early chapters, but the bulk of *Schedules* is the 921 figures and their accompanying description. This atlas of figures contrasts sharply with the careful, analytical development in earlier books by Skinner (*The Behavior of Organisms* and *Science and Human Behavior*) and even more with other books in psychology. An account of why *Schedules* is such a different book will give some perspective on the historical importance of the research and may help those approaching the book for the first time to understand it and appreciate its significance.

Ferster and Skinner discovered the incredible power of schedules of reinforcement to engender patterns of behavior. Their own behavior was so reinforced by the phenomena associated with schedule-controlled respond-

ing that, with the aid of automated equipment, they did research 24 hours a day, 7 days a week, year after year. Skinner had stable research funds from the Office of Naval Research that permitted Ferster and him to do uninterrupted research. Skinner did not publish any of this experimental work except for a report of a paper given at the 1951 Congress of Psychology in Sweden, and Ferster wrote one technical article about how to do research on operant behavior and published three experimental papers. Rather than stopping research to write reports, new experiments were planned on the basis of the results of those just conducted. Progress was evident from the capability to do experiments that were not possible or even conceivable earlier.

In the Festschrift volume for B. F. Skinner, Ferster gives a good description of the activities of the pigeon lab. He properly emphasizes the effort that went into technical developments and the availability of shop facilities to build equipment. Keys and feeders were tried and improved in a dozen iterations. The cumulative recording of responses, where each response causes a constant step movement of a pen perpendicular to the constant rate of movement of the paper, deserves special comment. Four different models of cumulative recorders were used, starting with one using a Ledex rotary switch as the main stepping mechanism and ending with a recorder build in the Psychological Laboratories by Ralph Gerbrands and later produced commercially by Gerbrands and Co. in a number of still more successively improved models. It was the cumulative recorder that permitted the recognition of the powerful effects of schedules. The information shown in a cumulative record is equally contained in a series of blips corresponding to the steps on a horizontal line of a polygraph, just as the information in most graphs can all be shown in a table of numbers. But the in-

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From: Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement*. Acton, MA: Copley Publishing Group. Reprinted courtesy of the B. F. Skinner Foundation, Julie Vargas, President, 11 Old Dee Road, Cambridge, Massachusetts 02138 (e-mail: info@bfskinner.org).

formation conveyed to the observer by the cumulative record, as with a graph, is far greater. Changes in rate of responding, indicated by changes in slope, are more obvious in the cumulative record than in a polygraph. The cumulative record shows at a glance the pattern of changes in rate of responding in real time over periods of hours or longer. The characteristic properties of different schedules would not have been discovered without the cumulative recorder.

When at last Ferster and Skinner turned to writing an account of their research on schedule-controlled behavior, they described all of it rather than summarizing the main findings. Dealing with the cabinets filled with cumulative records from experiments over several years was a Herculean task that would have overwhelmed most people. Ferster and Skinner took to writing *Schedules* with boundless enthusiasm. Long before multiple schedule control had been discovered as an experimental phenomenon, it had been Skinner's practice to bring his professional activities under strong stimulus control by working without interruption in a particular place. The room with the cabinets of records was made the writing room. There were log books of the daily experiments, giving the details about schedules, parameter values, and the subjects that were studied each day. With these books it was possible to retrieve the records for all experiments. Ferster stopped doing any research (freeing about 10 independent experimental units for use by deserving graduate students), and for a long period neither Ferster nor Skinner came into the pigeon lab except for a look at the cumulative records of experiments after they had finished their daily stint of figure preparation.

Ferster's Festschrift description of the mechanics of preparing the figures captures the flavor of their joint activities. The general practice was for Ferster and Skinner together to look at cumulative records for each subject studied in a particular experiment and select records to be photographed. This selection was undoubtedly the most important intellectual activity involved in the creation of *Schedules* and its success is indicated by subsequent workers confirming the important characteristic features of schedule performances described in *Schedules*, but it is impossible for a reader now to assess how the selections were

made or to appreciate the extraordinary talent required to understand the details of the records and to recognize the salient and replicable features. In Ferster's account of writing *Schedules*, he says "decisions about what to excerpt were made quickly, usually without much discussion, because we were both so familiar with the records." Because space limitations made it impossible to show photographs of all records as they were recorded without sacrificing details, they devised a method for collapsing the time scale by "telescoping" the pen tracings (pp. 26–27, also described by Ferster). Skinner loved making useful mechanical devices and also took pleasure in working with his hands, cutting out the pen tracings and pasting them on cardboard perfectly aligned with the coordinate scales showing representative slopes. Ferster later photographed the numbered figures in a part of the room equipped with a lighted stand and permanently mounted camera. After figures were mounted on cardboard, generally both Ferster and Skinner sat together and reviewed them, dictating descriptions of the figures, but sometimes Ferster alone dictated the descriptions. It is clear from reading the text that there was not much editing of the dictations, but Marilyn Ferster (later Gilbert) did do a final editing for consistency of usage. And in this way the accomplishments of their years of research were preserved for posterity.

Unfortunately, the importance of the work was not made obvious to the casual reader. The introductory sections of the book are helpful, but not enough explanatory material is presented to make parts of the book completely understandable to the uninitiated reader. The material in the introductory chapters explains the use of frequency of responding as an experimental datum, technical features about the experiments, the behavioral processes assumed to be important, and special features of fixed-ratio and fixed-interval schedules. Many figures show that responding can be differently controlled by different schedules hour after hour, day after day, without any broad conclusions about the importance and significance of these findings being made explicitly. Readers who understand the figures will certainly appreciate that Ferster and Skinner's studies were extraordi-

nary, but even understanding the figures requires much work for the reader.

The summaries are mostly about particular individual experiments and there is little in *Schedules* to help a reader determine the optimum conditions for engendering definitive schedule performances characteristic of particular schedule conditions. Readers must work through the examples for themselves and undoubtedly some give up. For the most part, there is no indication of the chronological order of individual experiments. Technical advances led to an increased degree of control in later experiments, but these are reported together with the findings of earlier experiments. (In an intermediate design of a cumulative recorder, the displacement of the stepping pen indicating food presentations was horizontal rather than downward [p. 25], and in general, figures showing this feature are from experiments conducted before 1952.) If one leafs through the pages of any chapter there are clearly differences in the uniformity and reproducibility of performances under a particular type of schedule. Some of these differences in performances came from the continuing technical improvements in the designs of keys and feeders, others from differences in the past experience of subjects before exposure to the current condition or from the duration of exposure to current conditions, and, sometimes, from differences between subjects treated alike. (But often Ferster and Skinner did not use subjects with a common past experience, believing that a consistent finding established in subjects with diverse backgrounds showed greater generality than one established in subjects similarly treated.) The reader is helped by the chronological description of individual experiments. The figures that show the sequential development of behavioral performances toward a consistent pattern during continued exposure to unchanging conditions will generally be understandable to readers. The figures that show terminal performances may be misunderstood because in *Schedules* "terminal" means only the last day of exposure to that schedule and the figure may or may not be representative of the steady state under the particular schedule conditions. Many of the figures or sequences of figures show transitions following a schedule or schedule parameter change. Even after

many sessions of steady-state responding, performances were generally immediately altered by changing the schedule contingencies. An important inference from such figures may be less evident: The features of schedules that are important in developing patterns of responding continue to operate in maintaining the patterns. It is not a matter of "learning" a pattern and then continuing to execute a "learned" pattern, but rather that the pattern of responding is maintained in steady state by the consistency of the schedule.

## II

What does it mean to say Ferster and Skinner discovered the power of schedules of reinforcement? Fixed-interval (initially called periodic reconditioning) and fixed-ratio schedules had been conceived and studied by Skinner in the early 1930s and he had made insightful analyses of their features. In *Schedules*, the experiments on tandem schedules and differential reinforcement of rate follow from Skinner's earlier analysis of the effects under ratio and interval schedules of different probabilities of reinforcement by inter-response times of different durations. In the course of doing these and other experiments on chaining, it became increasingly clear that responding in any pigeon could be brought under discriminative stimulus control and reproducibly maintained for hours with suitable schedule parameters and past experience. Schedule histories, the sequential intertwining of responding and contingent consequences, are the primary determinants of current behavior. This basic fact had not been fully appreciated, even by Skinner, before this time. A dramatic way to show this new understanding is to describe the background for the first experiments on multiple schedules that evolved from studies on chained schedules.

It is now widely accepted that the behavior of an individual is generally under stimulus control and may differ under different circumstances, but there were no laboratory experiments to show this explicitly until the 1950s. The concept of multiple behavioral repertoires under stimulus control was not part of any earlier psychological literature (consider how different *Science and Human*

*Behavior* would have been without such a concept). In contrast, the chaining of sequential responses had been an established principle of behavior with experimental foundations from the time of Skinner's earliest work. It was a natural development for Ferster and Skinner to extend the concept of chaining by conducting systematic studies on chained schedules.

In a chained schedule, responding under a schedule in the presence of one stimulus produces a second stimulus, in the presence of which responding under another schedule is reinforced with food, water, etc. In studying two-component chained schedules where the initial and terminal components were different schedules, Ferster and Skinner observed instances in which the pattern of responding in each component was characteristic of the respective schedule. For example, in Fig. 841, segment A shows the performance in the initial component (a 2-min fixed-interval schedule maintained by the onset of the stimulus for the terminal component) and segment B shows the terminal component (a 3-min variable-interval schedule maintained by food presentation). A reader who has worked through *Schedules* up to this figure will understand that responding in the two components is recorded separately and that following each mark on the response record in segment A the stimulus changes, record A stops and record B starts recording responses in the other stimulus condition. Following food presentations marked on the record in segment B, responses in the initial component are again recorded in segment A. It was clear from cumulative records such as those shown in Fig. 841 that the performances in the two components were appropriate to the prevailing schedule condition. In a moment of insight, Ferster and Skinner realized that the performance in the initial component maintained by the stimulus change would also be maintained by food presentation. When this proved to be the case, multiple schedules became an experimental reality.

Under a multiple schedule, two or more independent component schedules, each with a distinctive discriminative stimulus, occur sequentially. Ferster had a favorite example of the power of schedule-controlled responding under multiple stimulus control, which is shown in *Schedules* in Figs. 640–642.

A pigeon that was being studied under a multiple schedule with 5-min fixed-interval and 275 response fixed-ratio components alternating after each food presentation began to pause for long periods during the fixed-ratio component (strained ratio). In several instances, changing to the stimulus of the fixed-interval component resulted in immediate responding that increased to the terminal rate for the interval schedule. In Fig. 642, after a pause of about 80 min in the ratio component the schedules were changed. In the presence of the fixed-interval stimulus the pigeon responded appropriately to that schedule and made over 300 responses during the 5-min interval. The long pauses in the ratio component were caused by the number requirement of the fixed-ratio schedule, yet an even greater number of responses were made under the fixed-interval schedule condition. Everyone knows that people behave differently under different circumstances, for example with their friends, their parents or children. Ferster and Skinner showed that repertory of different patterns of responding, each under discriminative stimulus control depending entirely on the schedule conditions, could be studied experimentally in laboratory animals.

The capability of studying responding under multiple schedule control completely changed what could be studied in behavioral experiments and the interpretative inferences that could be made. Prevailing psychological theory before the 1950s relied greatly on generalized states (drive reduction, anxiety, etc.), as explanations of behavior. Earlier work on schedule-controlled behavior had established that the pattern and output of responding varied with different schedules. With multiple schedules it was not apparent that discriminative stimuli associated with different schedule conditions could, at any time, control separate behavioral performances. Explanations of behavior in terms of generalized motivational states are untenable when an individual responds in different ways depending on the history of contingencies associated with the current stimulus conditions. The later findings, that the effects of drugs could differ and even be opposite in direction under different components of multiple schedules occurring during brief time periods, further established the biological signif-

icance of schedule-controlled responding under stimulus control.

Amazingly, most of the research presented in *Schedules* was conducted in only a four-year period from 1950 to 1953 and during the beginning part of this period there were continued modifications of apparatus, as described in the reminiscence by Ferster cited earlier. The pace of work generated great excitement in those familiar with it and clearly this fantastic research outpouring would have been slowed had Ferster and Skinner interrupted it by publishing research papers in the more conventional way. Yet the impact of the work was diminished by the limited analysis and interpretation of the results and elucidation of their significance in *Schedules*. Indeed, even Skinner's own writing after the 1950s did not as thoroughly incorporate these discoveries as one might have expected. When Skinner was actively involved in the conduct of research, his broader writings emphasized the sequential interplay between an individual's responding and the consequences of responding that characterize schedule-controlled activities. In later writings he gave a greater emphasis to contingencies than to the interplay of the behavior with contingencies. Probably this would not have happened if Ferster and Skinner had taken more time to analyze

the important influence of exposure to prior schedule conditions in determining subsequent schedule performances.

In retrospect, it seems surprising that the concepts of multiple schedule control and schedule-controlled behavior were not appreciated earlier by individuals knowledgeable about operant behavior. While the significance of the work described in *Schedules* remains unfamiliar to most individuals interested in behavior, the technical advances that came from this work are evident everywhere behavioral research is conducted. Unfortunately there has been a decline in the use of the most important technical feature of the work, the cumulative recording of responses in real time, which Skinner considered to be his most important scientific contribution. At Indiana University and after he returned to Harvard University, Skinner had planned to apply the already developed techniques of operant behavior to the analysis of traditional psychological concepts, such as thinking, seeing, and attending. These plans were changed when schedule-appropriate behavior under discriminative stimulus control emerged as the primary determinant of an individual's behavior. *Schedules of Reinforcement* documents this important discovery in a highly original way.

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